



IN THE UNITED STATES PATENT & TRADEMARK OFFICE

International Application No.: PCT/DE03/002399

International Filing Date: 13 July 2003

U.S. Application No.: 10/520,826

U.S. Filing Date: 6 January 2005

Priority Date: 14 July 2002


By: Sauter

For: Bed Water Sampling Device

**English Translation of Applicant's Originally Filed
German Language Specification, Claims and Abstract**

Translator's Certificate

I, Karl Hormann, being fluent in the English and German languages, hereby certify that the appended, to the best of my knowledge and belief, is a true and accurate translation from German into English of Applicant's specification, claims and abstract.


Karl Hormann

Given at Cambridge, Massachusetts,
this 7th day of January 2005.

5

Bed Water Sampling Device

Specification

The invention relates to a bed water sampling device for
10 simultaneously taking several water samples from the lowest column of water
at different heights above the water bed by several cylindrical sample
containers which at at least one of their front surfaces are provided with a
closure actuated by a time-controlled release and which are horizontally
oriented for vertical adjustment on a central support rod which terminates in a
15 bottom element and which may be deposited on the water bed by a steel
cable attached to its opposite end .

The taking of water samples from the lowest water column, i.e. the bed
water above the water bed serves geochemical, oceanographic and (micro-)
20 biological investigations of the transition zone between the water bed
(sediment) and the column of water disposed above it. Different exchange
processes between these separate sections generate steep gradients of
parameters, e.g. in geochemical material concentrations and particle contents
which often are very closely intermingled with biological life processes. A bed
25 water sampling device should make high-resolution sampling possible, i.e.
sampling at several levels above the bottom of the body of water, the
transition zone, in order to allow new insights into the transport and reaction
processes prevailing there.

30 Basically, a distinction has to be made between two types of bed water
sampling devices: Arrangements which draw in the water samples from
different levels above ground and those in which the water is "caught" by

sampling containers arranged at different levels above ground, usually in a horizontal orientation. Among the first mentioned group (taking samples by suction) is, for instance, the water scoop (BIOPROBE) for depths of water up to 600 m in which several sample bottles are vertically arranged on a tripod frame, as mentioned in publication I by L. Thomsen et al.: "An instrument for aggregate studies in the benthic boundary layer" (Marine Geology, 135 (1996), pp. 153-156). Water samples are drawn into the bottles from different levels of the water column by means of suction hoses of different lengths. The disadvantage of this is that while bed water particles may be sampled, their original condition is disturbed by suction of the water samples through the suction hose. Also, the water sample may be subjected to degasification during the suction operation. However, gases dissolved in water often are parameters to be examined. The sample scoop is activated from the water surface, usually from a ship, by a single conductor cable. Since the sampling lasts a relatively long time (30 to 60 minutes), drifting of the ship during the sampling operation may lead to damage of the single conductor cable as a result of twisting. Repairing the single conductor cable by shortening it and renewed placement of the deep sea probe is both very time consuming and expensive. The cable cannot be used for a day otherwise available for taking measurements. Even if the sampler is mounted on a wide-spread tripod frame to minimize current-conditioned eddying and, hence, mixing of the water samples originating from different horizons, its action cannot be avoided altogether. In addition, the suction snorkels themselves constitute flow impediments, so that higher sampling horizons in particular are affected by flow dynamics of any of the more deeply suspended snorkels.

Modifications of the known BIOPROBE water scoop may be gleaned from publication II by L. Thomsen: "Processes in the benthic boundary layer at continental margins and their implication for the benthic carbon cycle" (Journal of Sea Research 41 (1999), pp. 73-86). In BIOPROBE III a hydrodynamically shaped sampler is eccentrically mounted on a mechanically rotatable arm which for the avoidance of mixed sampling is aligned before

sample taking in the benthic current by a current sensor. The sampler is vertically arranged and is provided with four sample chambers of 10 l capacity and intake nozzles through which the sample water flows in, at different but rigidly defined levels within a relatively small range of heights (between 5 and 40 cm). However, the principle of nozzles still renders the taking of samples free of particles and without loss of gasses as well as prior rinsing of the sample containers by original bed water problematic. Although current from a battery renders BIOPROBE III self-contained so that it may be used without a single-conductor cable, yet since it is dropped into the water as a free falling apparatus (lander), its recovery operations are time-consuming.

The most closely related state of the art, upon which the present invention is based, is a bed water sampler with an arrangement of horizontally oriented sample containers as described by A. Murdoch et al. in their book "Handbook of Techniques for Aquatic Sediments Sampling", 2nd edition, pp. 105-106. In this deep sea bed water sampler, several sample bottles structured as cylindrical sample containers, each of 3 l capacity, are mounted and secured against rotation on a central aluminum rod and arranged at different heights changeable over a range of 1.6 m. For its stabilization the central support rod is rigidly mounted on a bottom plate functioning as a bottom element and is supported by three cantilevers. The cantilevers are in turn tensioned by wire cables to a tripod at the upper end of the support rod. This is where a simple wire cable for lowering the sampler is also attached. While it is being lowered, the sampler and, with it, all the sample bottles are not aligned with the current. At one of their end surfaces, the sample bottles are provided with a closure structured as a slidable piston bottom. Their sliding motion is induced pneumatically by a bottle of compressed gas and is controlled by a pressure-protected electronic time release. The sample bottles are to be filled with sample water by way of the piston bottom which results in backup pressure in the interior of the bottle, however, and which may cause disturbance in the taking of the samples such as, for instance, loss of dissolved gasses. Further disturbance during the taking of samples

may be caused by the sample bottles not being aligned in the direction of the current so that the sample containers cannot be flushed out by original bed water and by the support cables of the support rod disturbing the current which may lead to mixed samples as a result of eddying.

5

A bed water sampler with horizontally oriented through-flow sample bottles is known from the joint program of several countries "PROVESS" - Process of Vertical Exchange in Shelf Seas - MAST III (see. PROVESS homepage by Rose Player, Proudman Oceanographic Laboratory, at

10 <http://www.pol.ac.uk/provess/html/main.html>, last updated on 17th April 2001, State as of 19 June 2002 (see photograph on page

http://pol.ac.uk/provess/photographs/b_w_sampler.gif, state 19th June 2002.

The photograph reveals ten horizontally oriented transparent sample bottles arranged in superposition on a support scaffold consisting of two parallel

15 support rods centrally fixed in a flaring four-legged frame weighted down by bottom weights. Apparently, the sample bottles are at each end face

provided with a closure lid which may be mechanically actuated by a cable mechanism. Hence, for taking samples, the water sample bottles may be freely flushed with water. Further details cannot be discerned from the

20 photograph. Nor does the PROVESS homepage impart further details about the displayed sampler. It can be seen, however, that the sample bottles are rigidly connected to their support frame and that they are surrounded by the four-legged frame. It is, therefore, not possible precisely to align the sample bottles relative to the current for flushing with original bed water and to rinse

25 away sedimentary particles which could have entered the containers while placing the device on the bed. Moreover, the bottom current is dynamically disturbed by the four-legged frame and its cross-braces, so that, again, mixed samples will develop as a result of eddying.

30 Proceeding from the closest state of the art discussed *supra*, the object of the present invention is to be seen in improving a bed water sampling device of the kind under consideration for the simultaneous

collection of several undisturbed samples of water from different levels of the lowest water column above the water bed by several horizontally oriented cylindrical sample containers so that undisturbed and high-resolution samples may be taken from the current adjacent to the bed in the material and particle
5 containing transition zone between the water bed and the column of water while substantially maintaining the original state of the water to be sampled. The improved bed water sampling device is to make possible taking of samples as quickly as possible, and in terms of handling it is to be simple and robust. Moreover, particles stirred up when placing the sampling device on
10 the water bed as well as water from other layers in the water column are to be flushed out of the containers by the original bed water prior to their closure.

In a bed water sampling device of the kind under consideration and described above, the object is accomplished in accordance with the invention
15 by the center support rod being connected between the weighted base frame functioning as a bottom element and the steel cable at low friction and for free rotation and provided with a flow vane, by the time-controlled release being encapsulated in the weighted base frame in a compression-proof manner for automatic actuation only a predetermined period of time after the base frame
20 has come to rest on the water bed and by the other end surface of the sample containers being also provided with a closure device actuated by the time-controlled release.

The bed water sampling device in accordance with the invention
25 combines high functionality to accommodate high-value water sampling demands. To be mentioned among these is the taking of samples from different water horizons free of any admixture and without suction and with a particular degree of field suitability, especially in view of the fact that the submersion cable may be freely selected, that the dwell time on the bed is
30 short and the resultant minimum requirements in terms of the position of the ship. In this respect, the relationship between the concept of the release for the simultaneous closure of all of the sample containers at both ends and

their simple and automatic alignment with the bed is essential. Since both ends of the sample containers are open before the samples are collected, genuine bed water may freely flow through them. Thus, at the instance both ends of the sample containers are closed, a sample of water is trapped in its free state of flow and, therefore, substantially original state. Since the water samples are collected without suction, any error-generating loss of gas in the water sample otherwise caused by the lowered solubility of gases in water as a result of suction-generated negative pressure is avoided. Alignment in the current is brought about by a sufficiently large flow vane rigidly connected to the freely rotatable support rod. The size of the vane is dimensioned such that even weak currents in the bed water zone close to the bottom will suffice to rotate and align the sample container on the central support rod in the current.

Furthermore, the time-controlled release ensures the taking of samples in undisturbed current conditions. The sample containers are closed only after any disturbances caused by placing the measuring arrangement on the water bed have subsided. Automatic actuation of the release takes place mechanically by upward pressure acting on a release plate disposed beneath the heavy base frame for a sufficiently long period, for instance one minute. In this manner, premature closure of the sample containers resulting, for instance, when accidentally placing the sampling device aboard ship during a placement operation, is substantially avoided. Moreover, because of the entirely mechanical actuation there is no need for a sensitive line for feeding control pulses from the surface of the water. The closure devices of the sample containers are actuated by an integrated time control - this may, for instance, be an electronic timer which, depending on its pressure capsule, can be applied at depths of 6,000 m and beyond, for instance - upon its actuation after a select time delay, e.g. a few minutes after placement of the sampling device. Hence, two integrated time loops are provided for a secure and flawless operation of the bed water sampling device in accordance with the invention.

In order to disturb the bed as little as possible the structure of the bed water sampling device advantageously has no exterior braces or tension wire devices. Flow dynamic mixing of layers of bed water by artificial turbulence is avoided. The stable vertical position of the apparatus on the water bed is
5 achieved, for instance, by a base frame weighted by lead ballast units. The bed water sampling device in accordance with the invention is suitable for deep sea operation and may, depending upon the stability of the pressure capsule of the release, be used in depths of water of 6,000 m and more. Overall, a bed dwell time of 5 minutes up to a maximum of 10 minutes is
10 needed for taking samples. During a time interval of so short a duration it is possible without any difficulty sufficiently precisely to maintain the position of the ship relative to the sampling device so that entanglements of, or kinks in, the sinking steel cable occurring in consequence of veering made necessary by the ship moving because of wind or surface currents, may with a great
15 degree of certainty be avoided.

An essential advantage of the bed water sampling device in accordance with the invention is the taking of bed water samples as undisturbed instantaneous records. For this purpose, it is important that
20 initially the bed current may flow through the cylindrical sample container. The sample cylinders are, therefore, provided at both end surfaces with closure devices which in their open state expose a relatively large cross-section of the sample containers. In one embodiment of the bed water sampling device it is, therefore, advantageous to provide the two closure
25 devices of each sample container with closure valves which in their open state are held in their open state against the bias of a return rubber tension device connected to a release shaft secured by a corrosive or burn wire. Subjecting the corrosive wire to an electrical voltage upon actuation of the time-controlled release causes it to rupture. Such a release arrangement is
30 robust and reliable in its operation and may easily be set up on board the ship from which the sampling device is deposited. Initially, the closure valves are biased toward each by a rubber tension band which may, for instance, extend

through the interior of the sample container and is fixed to a release shaft. The release shaft, in turn, is retained in its position by a burn wire. The burn wire is then charged with an electric current by the time-delayed actuation of the time-controlled release and after a further time delay following the
5 placement of the sampling device on the bottom of the sea. In the well-conductive sea water the wire will corrode through in one to three minutes and release the release shaft thereby to cause all the closure valves to close simultaneously.

10 For purposes of a non-invasive taking of samples it is important that transfer of the water samples for subsequent examination onboard the ship take place with little mixing with air in order to prevent an unintentional absorption or discharge of gases from or into the atmosphere. In accordance with a further advantageous embodiment of the invention, every sample
15 container may for this purpose be provided with a water discharge valve and, diametrically opposite, an air intake valve. In this manner, the air replacing the water flowing out of the container may uniformly flow into the container without any mixing of water and air. Any exchange of gas with the atmosphere is thus limited to a minimum. In accordance with a further
20 embodiment of the invention the sample container are transparent. In this manner it is possible to obtain an indication of the particle content and particle structure in individual water samples during the taking of the samples have been taken, by a camera, for instance, or by photographing or visual inspection before the sample is discharged on board ship.

25 The bed water sampling device is suitable for great depths of water. Because of the pressure conditions prevailing at such depths, the water has a certain gas absorption capacity. In order to prevent degasification during transfer of the samples to areas of lower pressure (up to atmospheric
30 pressure) the sample containers and both closure devices, in accordance with a further embodiment of the invention and as alternatives to the transparent kind, may be structured to be compression-proof. The complete preservation

of the original condition of the water derived therefrom may lead to invaluable additional findings. Compression-proof sample containers for sea depths up to 6,000 m may be made of a compression-proof material, such as steel or special titanium alloys, in particular.

5

Samples from the bed water column should be taken at high resolution at about 2 m above ground at several water horizons with at least 5 l being required per horizon for an isotropic analysis. For that reason it is advantageous, in accordance with a further embodiment of the bed water sampling device, to array a total of six sampling containers at a height of 2 m with each container having a capacity of 5 to 6 l. Six sample containers lead to the sampling of six water horizons which extend at a vertical distance of about 30 cm relative to each other so as to ensure a high resolution of measurement of the vertical water column. At this point it is to be mentioned that the individual sample containers on the central support rod may be disposed at a constant as well as a variable spacing from each other. The number and positioning of the sample containers are dependent upon the resolution profile to be provided which in turn is a function of the occurring measuring parameters. Using 6 vertically adjustable and horizontally oriented sample containers of about 6 l capacity each, the individual water samples will each be taken from layers of water of a thickness of about 10 cm which while positioned sufficiently close to each other do not, however, influence each other.

25 Since the bed water sampling device in accordance with the invention does not use braces and tension wires which would interfere with the bed current, the stable vertical position of the apparatus is ensured by the base frame being weighted by ballast units made of lead, for instance. Furthermore, in another embodiment of the invention several buoyancy units may be attached to a steel cable above the sampling device. For instance, two buoyancy units may be mounted about 15 m above the sampling device, and in concert with the ballast units effectively prevent the bed water

sampling device in accordance with the invention from overturning.

A preferred embodiment of the invention will be explained hereafter with reference to the schematic drawings, in which:

5

Fig. 1 are diagrams showing typical parametric curves; and
Fig. 2 depicts an embodiment of the bed water sampling device in accordance with the invention.

10 The main purpose of the bed water sampling device in accordance with the invention is to take vertically staggered samples of high-resolution quality so that profiles of vertical measurements may be provided. Especially in the transition zone between the bottom of the body of water and the water column disposed above it up to a range of about 2 m the measurement
15 values to be recorded often display steep gradients. These may be seen, for instance, in Fig. 1 the upper diagram of which depicts the curve of the oxygen content O_2 and of the ammonium content NH_4^+ in μM (micro mol) above the height in cm above ground at a depth of 2,500 m at the measuring site "AWI-Hausgarten" west of Spitzbergen. By comparison, the lower diagram of Fig. 1
20 shows the content of dissolved methane (dissolved methane in nmol per l of sea water) in bed water, again at the "AWI-Hausgarten" site at a depth of 2,500 m (left curve, low values) and, additionally, above the "Hakon Mosby" mud volcano at a depth of 1,260 m (right curve, high values). The different parameter curves at different levels above a common deep sea sediment
25 ("AWI-Hausgarten") and above the surface of the mud volcano, respectively, in the water column close to the bed may be clearly seen here which approximate each other only beginning at a level of about 2 m.

Fig. 2 shows a bed water sampling device 1 in accordance with the
30 invention for simultaneously collecting several water samples at different levels from the lowest water column above a water bed (dimensions in mm). Six sample containers 3 are arrayed at different heights on a center support

rod 2. In the selected embodiment, the distances increase upwardly over a length of 2 m so that a particularly high resolution may be realized in the lowest, close-to-the-bed layer of water. By means of a bearing 4, the center support rod 2 is journaled on a shaft 5 extending through it by means of a bearing 4, and is provided, for alignment with the water current near the bed, with a rectangular vane 6 which in the selected embodiment measures about 1 m². The lower end of the center shaft 5 is rigidly connected to a base frame 7 weighted by lead ballast. A vertically movable release plate 8 is provided in the center of the base frame 7. A common steel cable 9 is connected to the upper end of the center shaft 5 by means of a shackle. Several meters above the bed water sampling device 1, a buoyancy device, not shown in Fig. 2, is attached to the steel cable 9 for maintaining it vertically taut. The tautness and the weighted base frame 7 result in a secure vertical stationary position of the bed water sampling device 1. It is further augmented by an alternating arrangement of the sample containers 3 in front of and behind the center support rod 2.

The release plate 8 is connected to a time-controlled release 10 which following a predetermined time delay, for instance 1 minute, is activated by a slight but lasting upward pressure of the release plate 8 when positioning the bed water sampling device 1. In order not to interfere with the free rotatability of the center support rod 2 about the center shaft 5 by cable suspensions, the positioning signal furnished by the release plate 8 is transmitted by a slip ring 11 to a compression-proof magnetic contact 12 which transmits the signal by way of a submarine cable 13 to the time-controlled release 10. During lowering of the bed water sampling device 1 all sample containers 3, which in the selected embodiment are transparent cylinders, are open at both ends 14, 15 (shown in Fig. 2, by way of example, at one sample container 3). The sample containers 3 are each provided with two closure devices 16 with closure valves 17. In their open state, they are biased toward their closed position by a rubber tension device 18 extending through the interior of the sample container 3 but maintained in their open state by cords 19 connected

to transverse bolts 20 on the release shaft 21 rotatable in the horizontal plane. The position of the release shaft 21 is secured by a corrosion wire 22. When the time-controlled release 10 is activated the corrosion wire 22 is subjected, after a dwell time electronically or mechanically set in the time control, to a voltage by way of an electrical line not shown in Fig. 2, and in the well-conducting sea water it will disintegrate within one to three minutes, depending upon the gage of the wire and the material of the wire. The release shaft 21 which is then no longer arrested in its position will rotate sufficiently under the tension of the rubber tension devices 18 of all the sample containers 3 for the transverse bolts 20 to release the cords 19 of the closure valves 17. As a result, the closure valves 17 will close both 14, 15 ends of the sample containers 3 almost simultaneously so that the bed water from the different water horizons instantaneously flowing through the sample containers 3 is trapped. The time-controlled release 10 is mechanically activated by the release plate 8; the corrosion voltage for releasing the closure device 16 is provided by a source of current integrated in the time-controlled release 10. The bed water sampling device 1 in accordance with the invention is thus self-contained and may be hoisted by the simple steel cable. No single conductor cable is required. For discharging the trapped bed water sample aboard ship without interference, the sample containers are provided with a water discharge valve 23 and, diametrically opposite, an air inlet valve 24. A sample storage bottle is connected to the water discharge valve 23 by a thin hose. Both valves are opened for the discharge. Intermixing of the admitted air with the discharging sample water is thus prevented.

The bed water sampling device in accordance with the invention is a simple but reliable sampling device by which excellent measuring results can be obtained. This was demonstrated by internal tests by the applicant of a prototype of the claimed measuring device in the northern Atlantic Ocean at depths of 1,260 m and 2,500 m, as well as in the Bay of Eckernförde at a depth of 25 m, for such measuring parameters as methane, oxygen, the

abundance of bacteria, nutrients, methane, radon 222 and sea water salt content at sampling times of a maximum of 7 minutes.

5

10

15

20

25

30

List of Reference Characters

- | | | |
|----|----|---------------------------|
| | 1 | Bed water sampling device |
| 5 | 2 | center support rod |
| | 3 | sample container |
| | 4 | bearing |
| | 5 | center shaft |
| | 6 | current vane |
| 10 | 7 | weighted base frame |
| | 8 | release plate |
| | 9 | steel cable |
| | 10 | time-controlled release |
| | 11 | slip ring |
| 15 | 12 | magnetic contact |
| | 13 | submarine cable |
| | 14 | end face |
| | 15 | end face |
| | 16 | closure device |
| 20 | 17 | closure valve |
| | 18 | rubber tension device |
| | 19 | cord |
| | 20 | transverse bolt |
| | 21 | release shaft |
| 25 | 22 | corrosion (burn) wire |
| | 23 | water discharge valve |
| | 24 | air inlet valve |

30